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## Occlusal and functional conditions after surgical correction of anterior open bite deformities

*The dental occlusion and alterations in orofacial muscles were studied in 267 patients whose severe anterior open bite had been treated with a Le Fort I intrusion osteotomy with or without an advancement sagittal split osteotomy about 6 years ago. Only 17% of those patients showed anterior contact, and 20% had no vertical overlap of mandibular and maxillary central incisors at all. Tongue position, activity of masticatory muscles, lip competence, lip-incisor relationship, and breathing mode were assessed. Statistically significant correlations were found between tongue positions and occlusion in both the anterior and the posterior regions. In addition, the activity of the masticatory muscles, habitual mouth posture, and interlabial distance were each significantly correlated to overbite, open bite, and overjet. The interlabial distance was also significantly correlated with both breathing mode and mentalis muscle activity. The activity of the masticatory muscles was negatively correlated with tongue position. (Int J Adult Orthod Orthognath Surg 1996;11:29-39)*

Typical features in individuals with anterior skeletal open bite deformity are negative overbite, mouth breathing, significant nasal airway resistance, a long, narrow face with reduced nasal width in the alar region, lip incompetence with straining of the mentalis muscle to achieve lip closure, excessive exposure of the maxillary incisors, excessive show of the gingiva during smiling, and convexity of the profile.<sup>1,2</sup>

Anterior open bite deformities present the orthodontist and the maxillofacial surgeon with specific diagnostic and treatment problems.<sup>3,4</sup> The etiology, diagnosis, treatment planning, and long-term prognosis of anterior open bite anomalies have traditionally been based mainly on the easily assessable skeletal and dental characteristics.

Because it is recognized that abnormal swallowing may contribute to malocclusion, more attention has been paid to activity and forces exerted by the tongue, lips, and cheeks.<sup>5-8</sup> The equilibrium theory, introduced by Weinstein et al<sup>9</sup> and later revisited by Proffit,<sup>10</sup> improved the understanding of relations between tongue and lip pressure and the position of the anterior teeth. The relationship between patterns of orofacial muscle activity and malocclusion, however, is still not clearly understood.

A Le Fort I intrusion osteotomy has proven to be an effective procedure to reduce the vertical height of the face. The associated alterations in soft tissues induce a chain of adaptive changes in the muscles and their functional behavior in the orofacial region. Aberrant soft

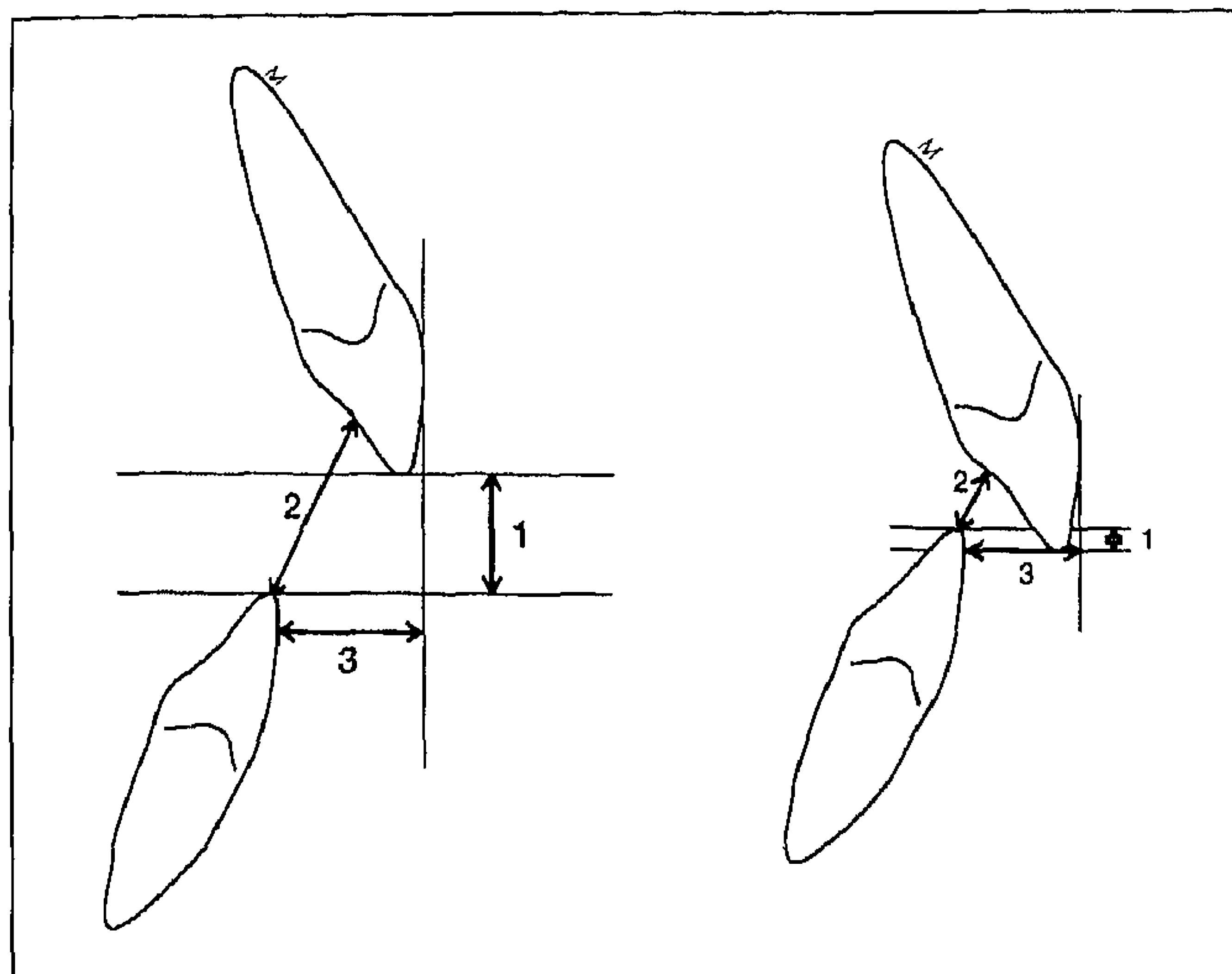


Fig 1 Measurement of overbite (1), open bite (2), and overjet (3). The overbite is recorded as negative or positive.

tissue functions are expected to adapt to the new dental arch form and occlusion. The range of adaptability of functional aspects, however, is considered to be limited in growing individuals.<sup>11</sup> Little attention has been paid so far to adaptive capacities of the orofacial complex in adults, particularly after surgical correction of severe open bites.

The aim of this study was to gain more insight into the role of soft tissues and functional aspects, their adaptation after surgical correction of open bite deformity, and their influence on occlusion.

## Method and materials

### Patients

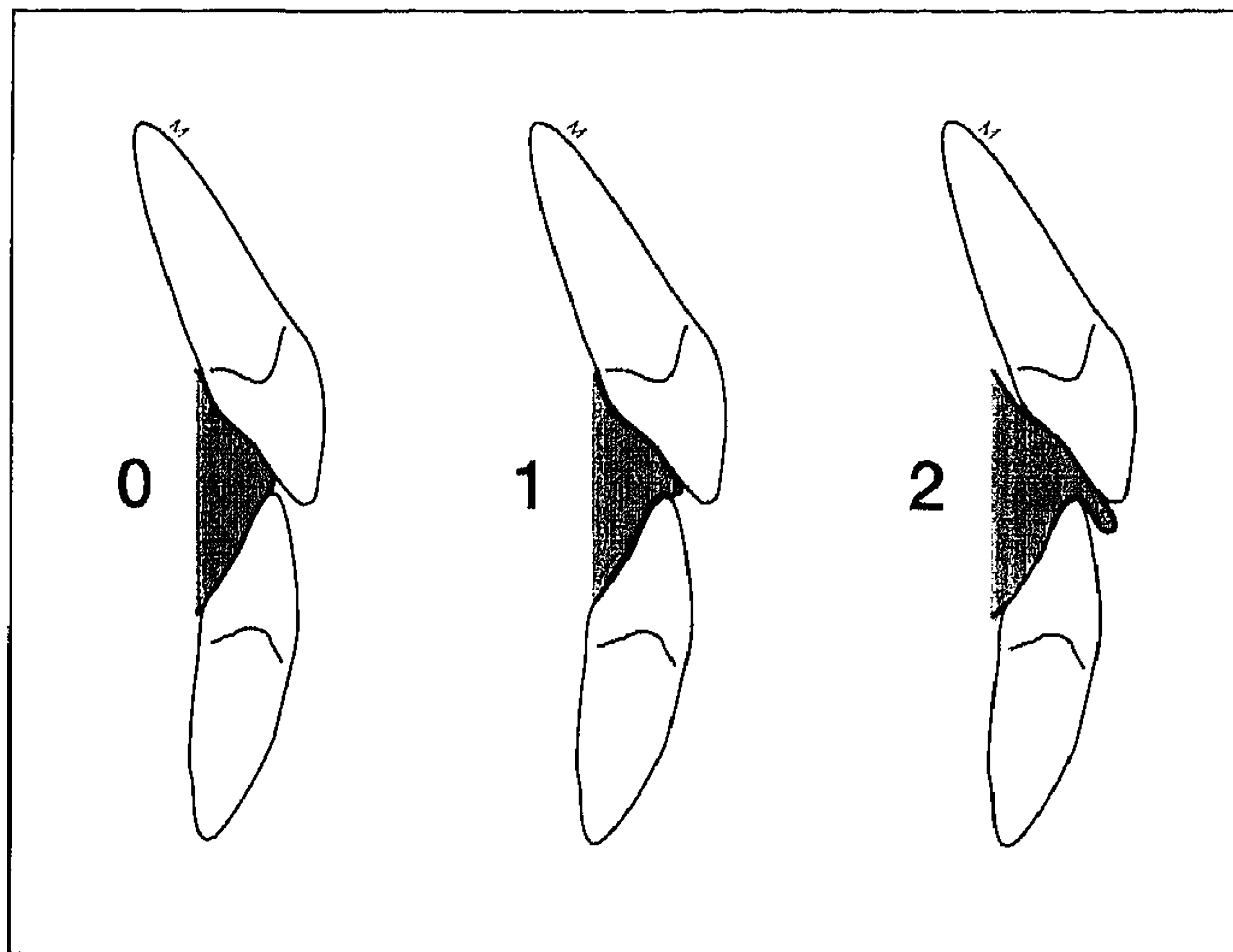
The study was based on 267 adults (210 women and 57 men), with a mean age before treatment of 23.6 years (range of 14.3 to 45.5 years). All patients originally had a Class I or Class II, division I, occlusion combined with an anterior open bite without vertical overlap of the central incisors. They had undergone surgical correction either in the department of Oral and Maxillofacial Surgery of the University

Hospital, Nijmegen ( $n = 72$ ), the Rijnstate Hospital, Arnhem ( $n = 72$ ), or the Free University Hospital, Amsterdam ( $n = 123$ ).

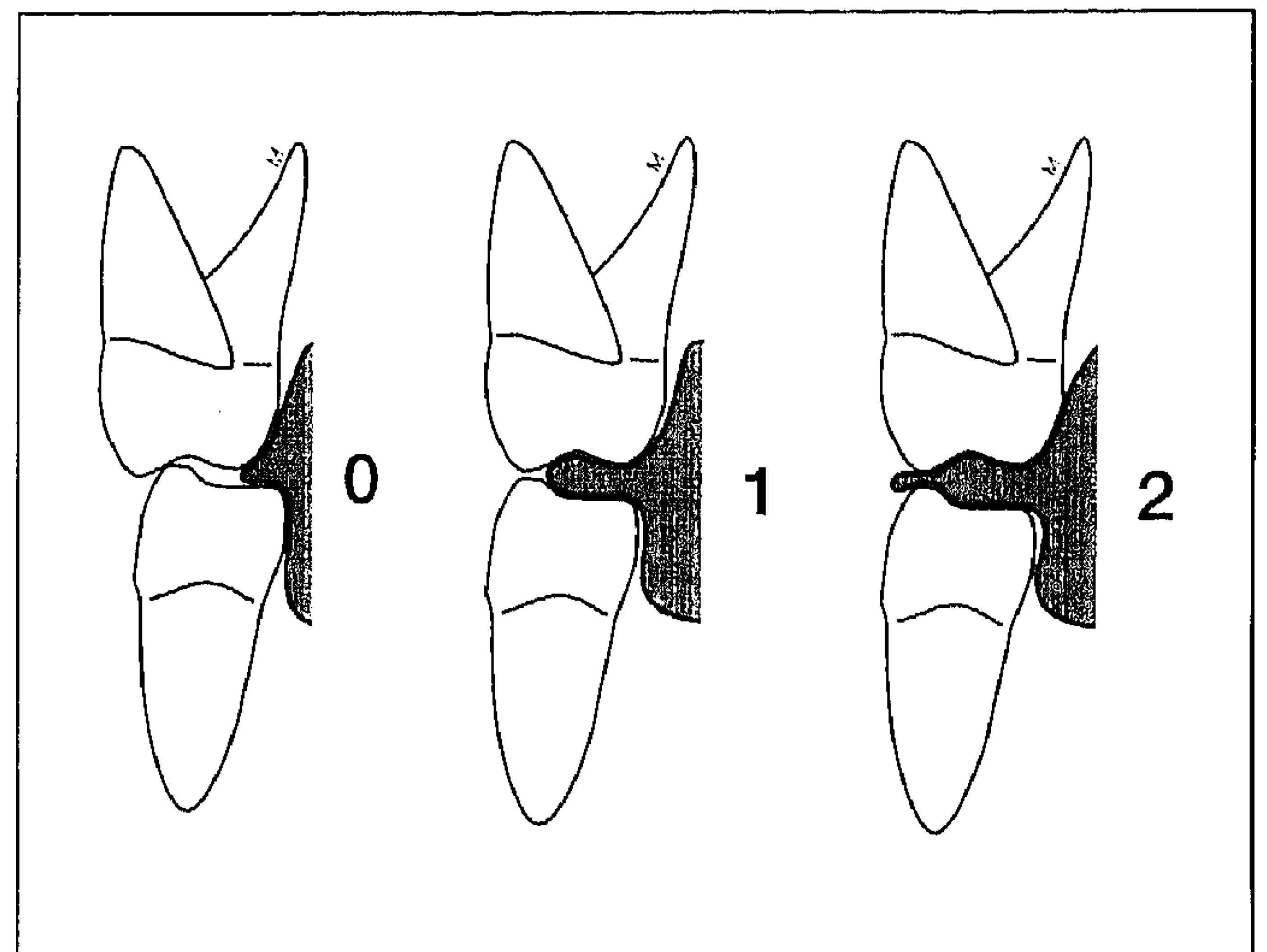
A Le Fort I intrusion osteotomy was performed in 144 patients. A combination of a Le Fort I osteotomy with a bilateral mandibular sagittal split osteotomy (BSSO) was carried out in 123 patients. Internal rigid fixation with plates and screws was used in 114 patients and internal wire fixation with intermaxillary fixation was applied in 153 patients. Standardized cephalometric radiographs were available preoperatively, immediately postoperatively, and at the latest follow-up. In addition, all patients were clinically assessed at the follow-up examination. The mean follow-up was 6.0 years (range of 1.0 to 17.8 years). Surgery was followed by orthodontic treatment in 203 patients; however, in all patients, the orthodontic treatment was completed at the least 1 year before the latest follow-up.

### Methods

In this study, an open bite was defined as the absence of occlusal contacts between opposing mandibular and



*Fig 2a* Tongue position is recorded with reference to mandibular incisors. The tongue tip is located lingually (0), on top of (1), or beyond the incisal edges of the mandibular incisors (2).



*Fig 2b* The lateral borders of the tongue are located lingually (0), on top of (1), or beyond the buccal cusps of the mandibular molar (2).

maxillary teeth or palatal gingiva. Only patients who had severe anterior open bite without vertical overlap between opposing incisors before treatment were included in this study. A clinical assessment of the dentition and functional aspects was performed while the patients were seated with their head in a natural upright position.

**Dentition.** The occlusion was assessed in the anterior region by measuring the overbite, overjet, and open bite and in the posterior regions by quantifying the interdigitation. The recorded overbite was the vertical overlap between the incisal edges of opposing central incisors measured perpendicular to the Frankfort horizontal plane. The overjet was considered the sagittal distance between the labial surfaces of the central incisors parallel to the Frankfort horizontal plane. The open bite was measured as the distance from the incisal edge of the mandibular central incisors, in the direction of its long axis, to the maxillary central incisors or the palate (Fig 1).

The interdigitation in the posterior segments was estimated by the number of occlusal contacts for each mandibular premolar and molar separately. Dental

floss was used to detect the points where occlusal contact was made. For that purpose, a three-point scale was used: no (0), one (1), or more than one (2) occlusal contacts. The overall interdigitation was quantified by dividing the total recorded score by the pairs of opposing teeth involved.

**Tongue.** The corner of the mouth was gently opened with two periodontal probes; subsequently, the tongue position was recorded while the mandible was in a resting position, when it was brought into maximal intercuspation, during speech (counting from 60 to 70), and during swallowing of saliva. The position of the tip and the lateral borders of the tongue were evaluated with reference to the adjacent teeth. The most protrusive position during swallowing was recorded. The position of the tongue tip was assessed, with a three-point scale, as being located lingually (0), lying on top of (1) or beyond (2) the incisal edges of the mandibular incisors. The position of the lateral borders of the tongue were differentiated as being located lingually (0), on top of (1) or beyond (2) the buccal cusps of mandibular premolars or molars (Figs 2a and 2b).



**Masticatory muscles.** The activity of the masseter and the temporalis muscles was evaluated by palpation while the patient clenched in maximal intercuspation and swallowed on command. To that end, the palms of the clinician's hands were placed over the anterior margins of the masseter and the temporalis muscles. The activity of each muscle during swallowing was related to its activity during clenching and was differentiated as negligible (0), moderate (1), or high (2) activity. Activity was considered negligible if no or little muscle activity was felt and high when the activity was comparable to those during clenching. Moderate was everything between. Final judgments were based on three observations. Because corresponding muscles on both sides act similarly, the right and left side data were pooled together. A similar three-point scale was used to assess activity of the mentalis muscle.

**Lips.** The habitual mouth posture was observed and qualified as open, variable, or closed mouth. The interlabial distance, or lip incompetence, was measured in millimeters while the mouth was at rest. The upper lip-maxillary incisor relation was measured in millimeters while the patient was exhibiting unforced closed lips, was at rest, and was smiling.

**Breathing mode.** The breathing mode was categorized as predominantly nose breathing, no preference, or predominantly mouth breathing. A sensation of a dry mouth after awakening in the morning was considered a sign of habitual mouth breathing during the night.

### Statistical Analysis

The reliability of assessment of tongue position and interdigitation score was expressed by Cronbach's  $\alpha$ . A second assessment of tongue position at rest, in maximal intercuspation, during speech, and during swallowing was carried out by another observer in 19 patients to check the reproducibility. Interobserver agreement was determined by means of Cohen's kappa. A *t*

test for independent samples and an analysis of variance (ANOVA) were done to detect the influence of the mode of treatment and the type of internal fixation on the overbite. A multiple regression analysis was used to determine correlations between several internal and external factors of orofacial function. Pearson's coefficients of correlation were calculated to determine the existence and the strength of any association between occlusal and functional conditions.

### Results

The assessment of the tongue position revealed a reliability coefficient  $\alpha = 0.79$  in the anterior region and  $\alpha = 0.81$  in the posterior region. The interobserver reliability showed a kappa score varying between 0.70 and 1.00, with a median of 0.88. For the assessment of the interdigitation, the reliability coefficient was 0.82.

The recorded activity of masseter and temporalis muscles correlated well ( $r = .98$ ), so the findings were combined into a mean score for the activity of masticatory muscles.

### Occlusal conditions

Long-term postoperatively, the mean overbite was 0.8 mm, and the median overbite was 1.0 mm (Table 1). No significant difference in this variable was found between the patients with only a Le Fort I intrusion osteotomy and those who had an additional BSSO. Neither was any significant difference found between the groups with either internal rigid fixation or wire fixation. The mean open bite and overjet were 2.3 and 3.4 mm, respectively. The mean interdigitation score was 1.5. The opposing central incisors made contact in 17% of the patients, and a solid interdigitation with a score of 2.0 was present in 36% of the patients. A positive overbite immediately postoperatively relapsed to an anterior open bite with a negative overlap in 20% of the patients.

**Table 1** Dental conditions in anterior and posterior regions

Measurement	Mean	SD	Median	Range
Overbite (mm)	0.8	1.4	1.0	-4.5-4.0
Open bite (mm)	2.3	1.8	2.0	0.0-9.0
Overjet (mm)	3.4	1.7	3.0	0.0-9.0
Interdigitation R	1.5	0.5	1.5	0.0-2.0
Interdigitation L	1.5	0.5	1.5	0.3-2.0

**Table 2** Anterior tongue position during different functional modalities

Function	0	1	2
Rest	53%	33%	14%
Occlusion	69%	25%	6%
Speech	72%	20%	8%
Swallowing	15%	33%	52%

Tip of the tongue located lingually (0), on top of (1), or beyond (2) the mandibular incisors.

**Table 3** Posterior tongue position in different functional modalities

Function	0	1	2
Rest	56%	39%	5%
Occlusion	82%	17%	1%
Speech	40%	47%	13%
Swallowing	46%	36%	18%

Lateral part of the tongue located lingually (0), on top of (1), or beyond (2) the buccal cusps.

**Table 4** Muscle activity of the masticatory and mentalis muscles during swallowing

	0	1	2
Masticatory muscles	36%	38%	26%
Mentalis muscles	1%	80%	19%

Muscle activity negligible (0), moderate (1), or high (2).

**Table 5** Mode of breathing

	Preoperative	Postoperative
Nose	22%	42%
No preference	20%	31%
Mouth	58%	27%

### Functional conditions

Tables 2 and 3 list the percentages of patients exhibiting different anterior and posterior tongue positions in different functional modalities. Severe tongue interpositioning (2) was most often seen in the anterior region during swallowing.

The activity of the masticatory muscles during swallowing was negligible in 36% of the patients. High activity by the mentalis muscle was required to achieve a circumoral seal (by raising the lower lip) in 19% of those examined (Table 4).

The mean interlabial distance was 3.0 mm (range of 0.0 to 12.0 mm). A

habitual open mouth posture was present in 35% of the subjects; however, lip competence was reached by 41%. The posture of the mouth varied in 24% of the patients. The mean distance from the incisal edge of the maxillary incisor to the upper lip was 1.0 mm with closed lips (range of -2.0 to 6.0 mm), 3.0 mm with lips at rest (range of -1.0 to 8.0 mm), and 10.0 mm while smiling (range of 4.0 to 15.0 mm).

Table 5 lists the preoperative and long-term postoperative modes of breathing. The percentage of patients exhibiting predominantly mouth breathing decreased from 58% to 27%.

**Table 6** Correlation coefficients between tongue position during different functional modalities and interincisal relationship

Tongue position	Interincisal relationship			Interdigitation	
	Overbite	Open bite	Overjet	Right	Left
Rest	-.38*	.47*	.35*	-.37*	-.36*
Occlusion	-.39*	.54*	.43*	-.43*	-.39*
Speech	-.42*	.41*	.24*	-.39*	-.26*
Swallowing	-.47*	.64*	.43*	-.59*	-.48*

\* $P < .01$ .**Table 7** Correlation coefficients between external aspects of orofacial functions and interincisal relationship

External factors	Overbite	Open bite	Overjet
Muscle activity			
Masseter/temporalis	.45**	-.41**	-.22**
Mentalis	-.09 NS	.19**	.10 NS
Open mouth posture	-.17**	.24**	.24**
Interlabial distance	-.20**	.30**	.29**
Incisor-lip relation			
Closed	.13*	-.01 NS	-.03 NS
Rest	.07 NS	.14*	.18**
Smiling	.02 NS	.15*	.13*
Mouth breathing	-.03 NS	-.03 NS	-.01 NS

\* $P < .05$ .\*\* $P < .01$ .

NS = not significant.

### Correlations

Overbite, open bite, and overjet each correlated significantly ( $P < .01$ ) to anterior tongue position at rest, in occlusion, during speaking, and during swallowing (Table 6). Significant correlations were also found between interdigitation and the lateral tongue position.

The activity of the masticatory muscles, habitual mouth posture, and interlabial distance were each significantly correlated ( $P < .01$ ) with overbite, open bite, and overjet (Table 7). The interlabial distance was positively correlated with mouth breathing and the activity of the mentalis muscle ( $P < .01$ ). Negative correlations were found between anterior and posterior tongue interpositioning and the activity of the masticatory muscles ( $P < .01$ ) (Table 8).

### Discussion

Vertical skeletal disproportions, postural positions of the upper lip in relation to maxillary incisors, and interlabial distances can be corrected permanently by repositioning of the maxilla with a Le Fort I osteotomy. That also applies to a lesser extent to anterior open bites. However, such an osteotomy has a direct effect on the volume of oral and

nasal cavity and an indirect influence on tongue position and mode of breathing.

Many studies on orofacial muscle activity and its effect on the dentition have been published. Pressure measurements, electromyography, cinefluororadiology, cinematography, and electromyography have been used in studies covering a wide range of malocclusions. Direct clinical observations of tongue position seem to be valid and reliable for diagnostic purposes.<sup>12,13</sup> The overbite and overjet are mostly used to record interincisal relationship. These variables, however, do not allow a useful recording of the amount of space between opposing incisors available for tongue interpositioning: the anterior open bite.

A more forward and superior position of the tongue tip relative to the mandibular central incisors at rest is seen in anterior open bites. The tongue is usually not in full contact with the hard palate, but is positioned against or between the incisors during swallowing. Tongue interpositioning in the posterior region at rest without palpable contraction in the masticatory muscles during swallowing is indicative of lateral open bite.

Few data on tongue position and lip posture after orthodontic or surgical treatment are available in the literature. Measurements of tongue pressure in



**Table 8** Correlation coefficients between different aspects of orofacial functions

Interlabial distance–mouth breathing	.22*
Interlabial distance–mentalis muscle activity	.39*
Anterior tongue interpositioning–muscle activity (masseter/temporalis)	–.54*
Posterior tongue interpositioning–muscle activity (masseter/temporalis)	–.64*

\* $P < .01$ .

orthodontically treated patients revealed that the mean tongue pressure in patients in whom an anterior open bite has relapsed is twice that of patients in whom no relapse is seen. In contrast, the lip pressure in the anterior open bite group was reported to be 65% of that in the normal group.<sup>14</sup>

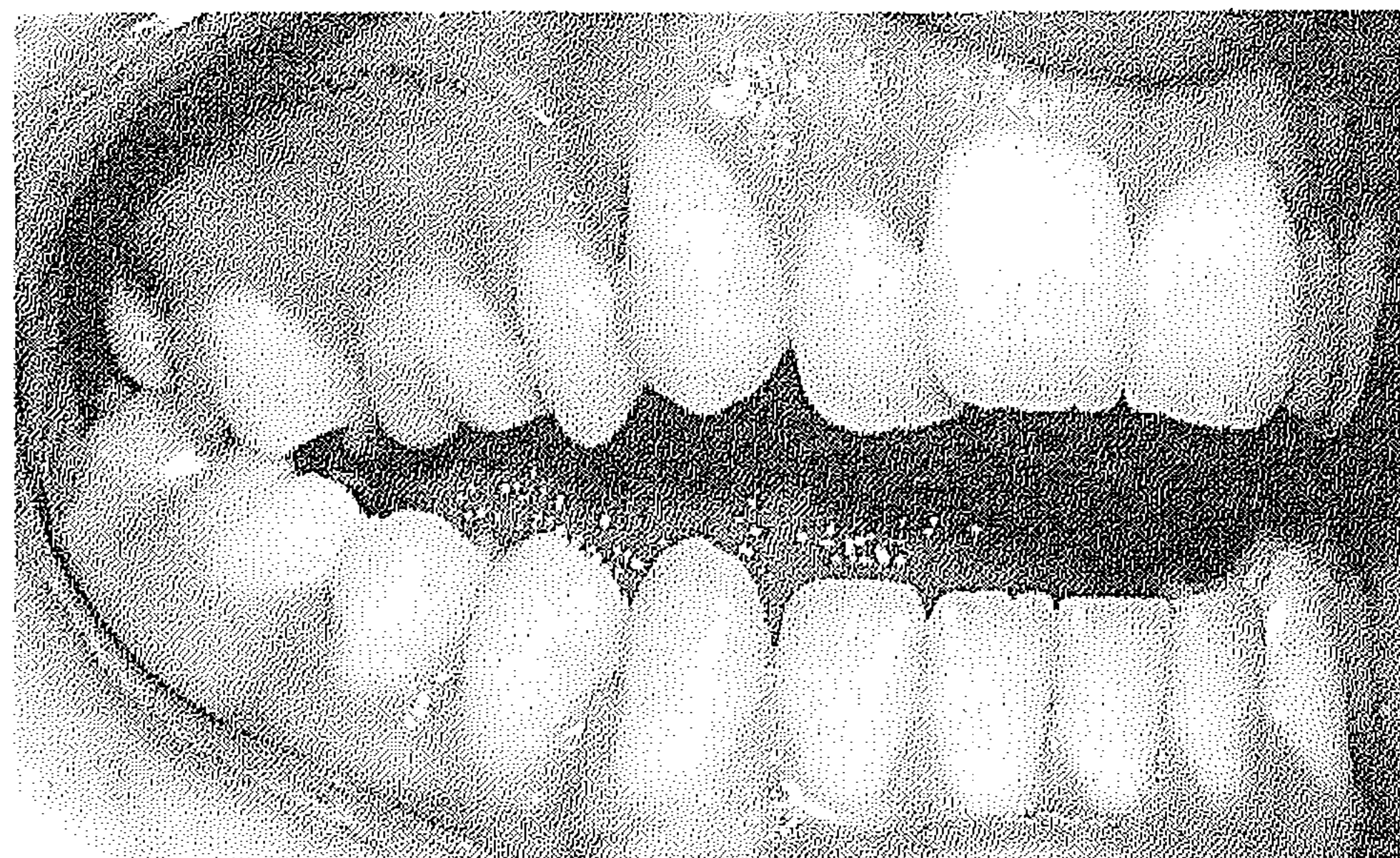
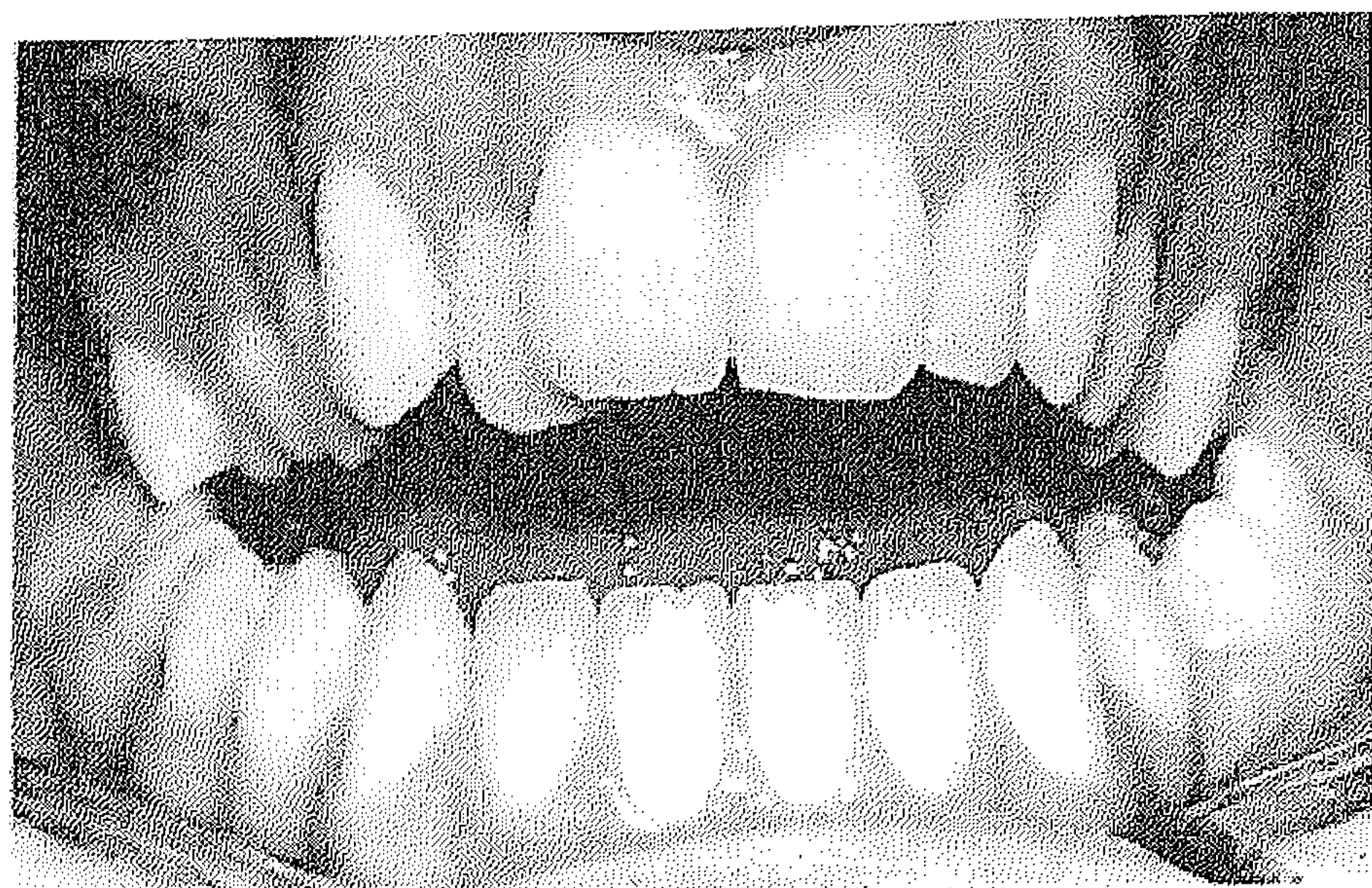
The effect of a Le Fort I intrusion osteotomy on tongue behavior was investigated in a prospective investigation on 18 patients, performed from 1984 to 1985.<sup>15</sup> Tongue behavior and swallowing patterns were observed during speech and evaluated by the use of a fluorescein-sodium fluid. A normal swallowing pattern was found in only 11.1% of those patients preoperatively and 17% of the patients 1 year after surgery. In the present retrospective study, in which those 18 patients were included, a normal position of the tongue, with reference to the mandibular incisors during swallowing, was assessed in 15% of patients.

The mutual interaction between form of the dental arch and lip-tongue-cheek function has been discussed by many authors.<sup>12,16</sup> It is obvious that the positions of the incisors and the tongue are correlated and act reciprocally on one another. The movements of the tongue are reported to adapt or vary in func-

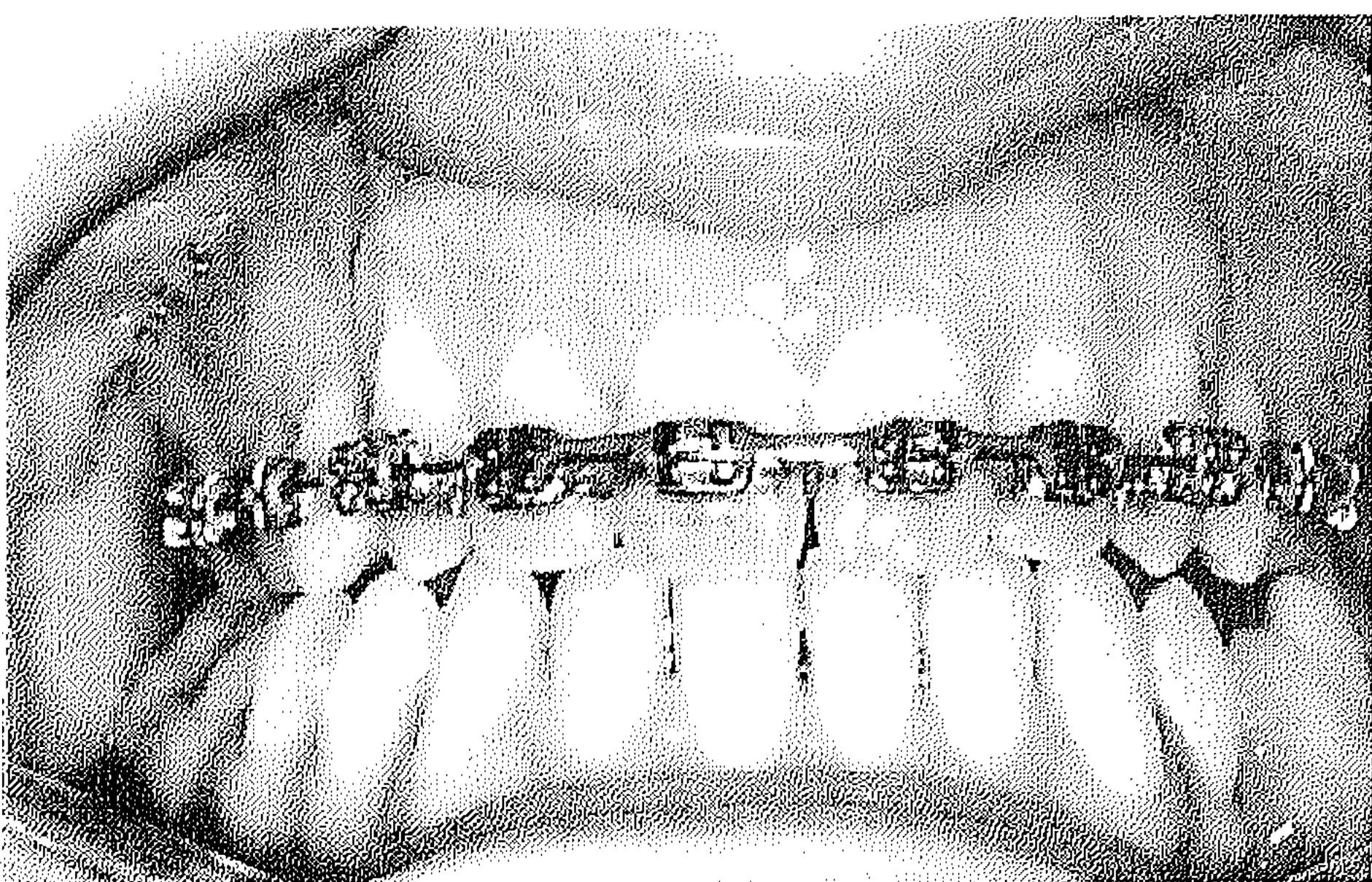
tion according to the situation in the anterior segment.<sup>17</sup> The tongue position and movements also adapt to reductions of the maxillomandibular space caused by osteotomy procedures,<sup>18–20</sup> which is in agreement with reported significant correlations between tongue volume and the size of the oral cavity.<sup>21</sup> The adaptive capacity, however, is quite limited. Lack of anterior contact and solid interdigitation allow tongue interpositioning. On the other hand, tongue interpositioning interferes with eruption or orthodontically assisted extrusion of teeth (Figs 3a to 3h).

Previous studies reported an objectively and subjectively measured decrease in nasal airway resistance after superior repositioning of the maxilla, with or without involvement of the nasal floor. This decrease, found in 56% to 82% of the patients, was caused by a widening of the nares and opening of the luminal valve.<sup>22–25</sup> A reduction in nasal resistance does not necessarily change the mode of breathing. Spalding et al<sup>26</sup> reported a decrease in nasal resistance but no change in percentage of nasal respiration in patients 1 year following a Le Fort I osteotomy. No significant correlation was found between the amount or direction of maxillary movement and nasal respiration. In a comparable study,

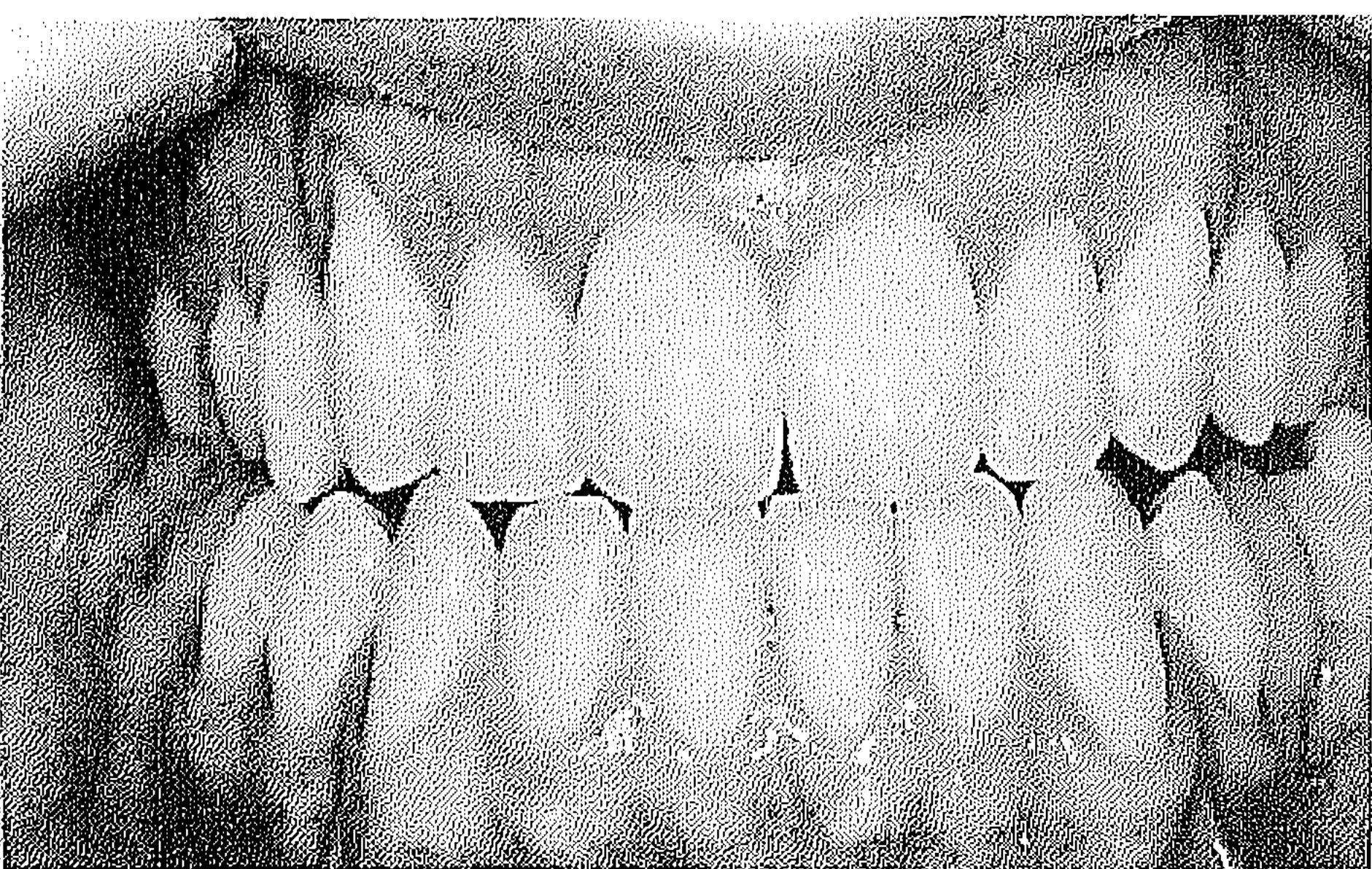




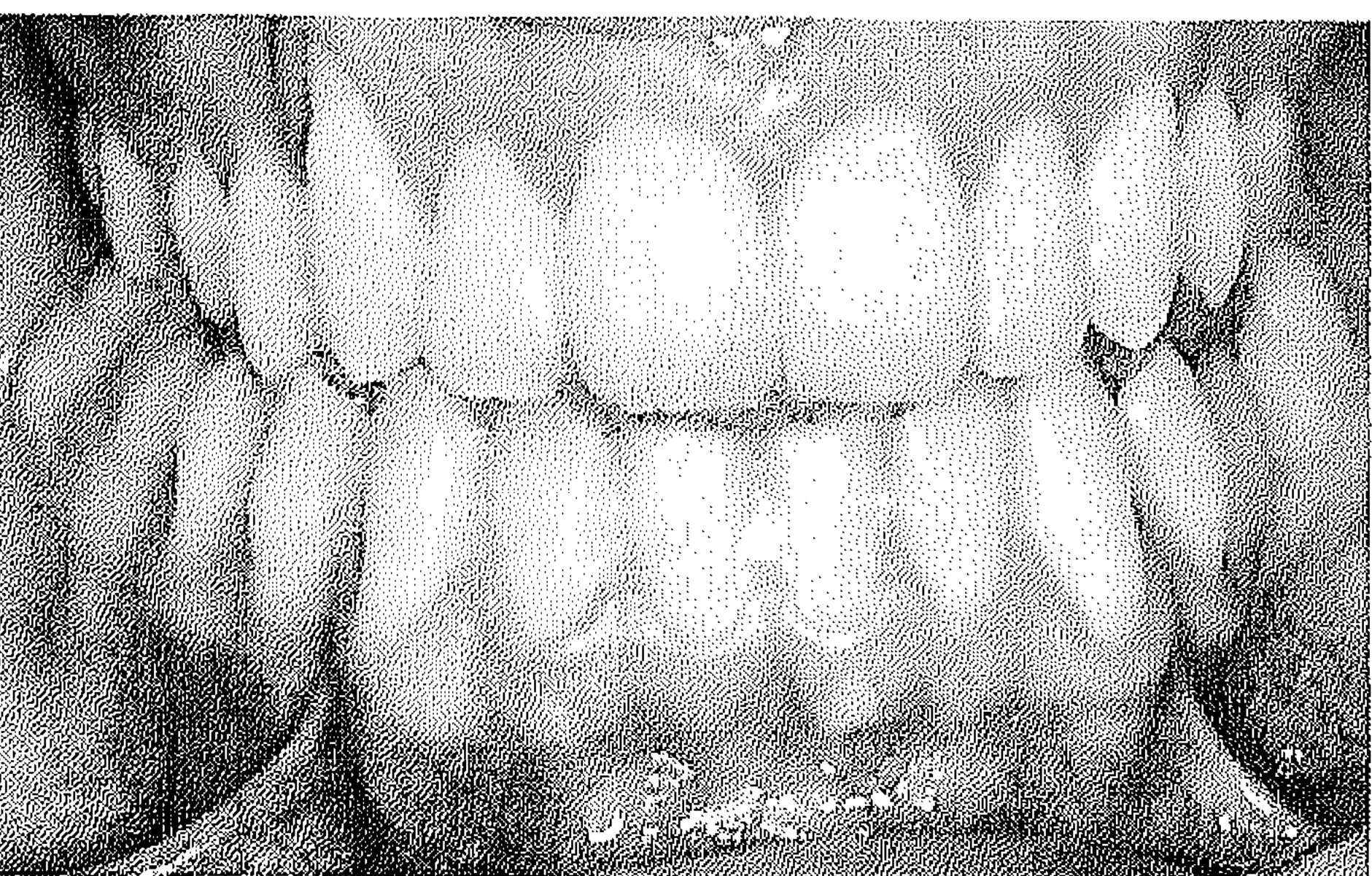
*Figs 3a and 3b* A 23-year-old man underwent preoperative orthodontic treatment for 12 months.



*Figs 3c and 3d* A one-piece Le Fort I osteotomy was performed. The maxilla was intruded 2.0 mm anteriorly and 4.0 mm posteriorly and was advanced 2.0 mm. Three months postoperatively, the orthodontic treatment stopped. Despite a 1.5-mm overbite, the interdigitation is not optimal.



*Figs 3e and 3f* One year 6 months postoperatively, the overbite has decreased to 0.5 mm, and the interdigitation has deteriorated.



*Figs 3g and 3h* Tongue interposition exceeding the incisors and premolars is apparent during swallowing and speaking. Tongue interposition between the incisors is present at rest and in occlusion. The masticatory muscles show no palpable contractions during swallowing.

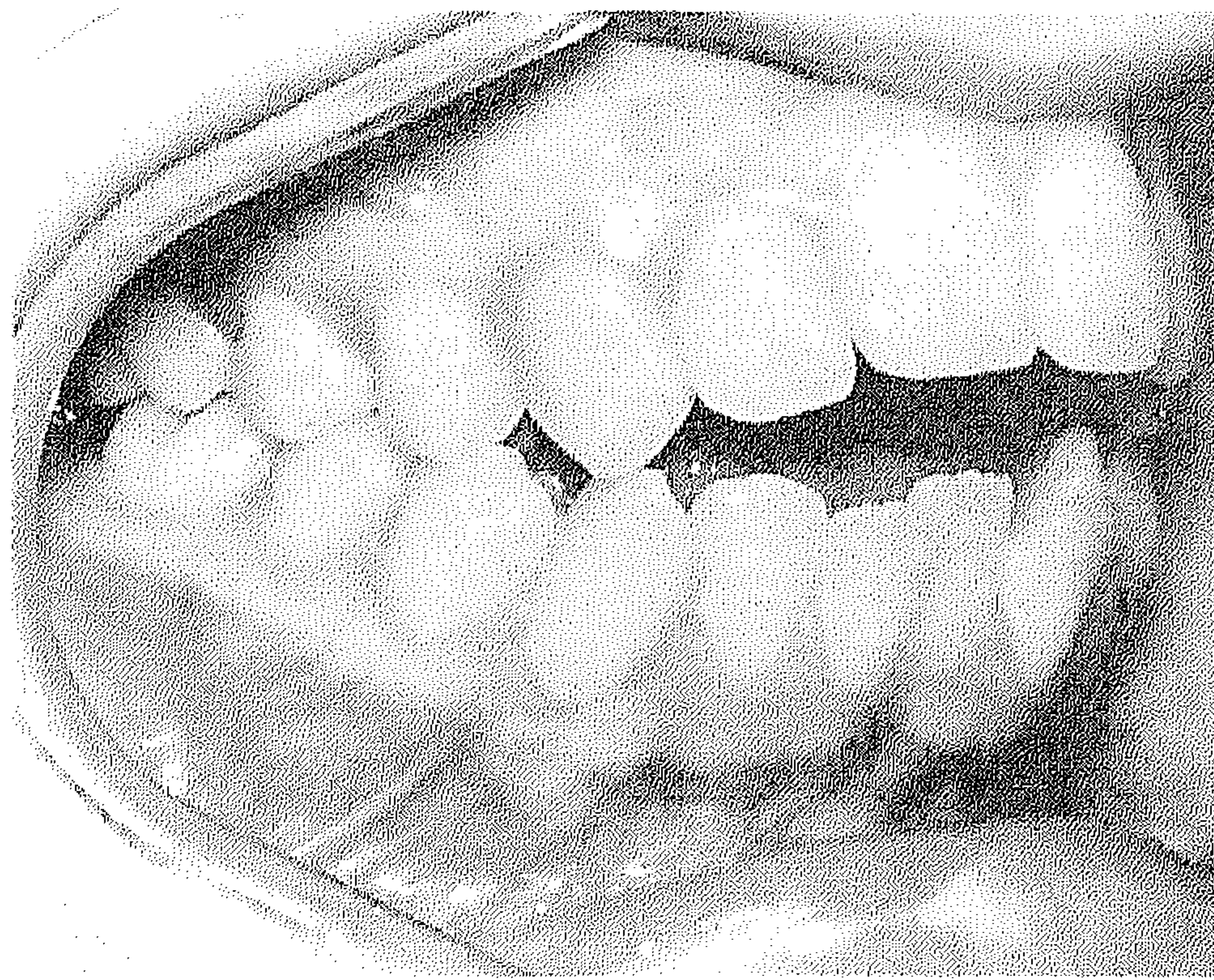
Walker et al<sup>25</sup> found, in a sample of 20 patients, a mean increase in nasal respiration from 60% preoperatively to 90% postoperatively. The latter findings were supported by the present data, in which there was a change from predominantly oral breathing preoperatively to mixed

oral and nasal or predominantly nasal breathing postoperatively in 31% of the patients. The recorded change in mode of breathing might be due to the increase in lip competency.

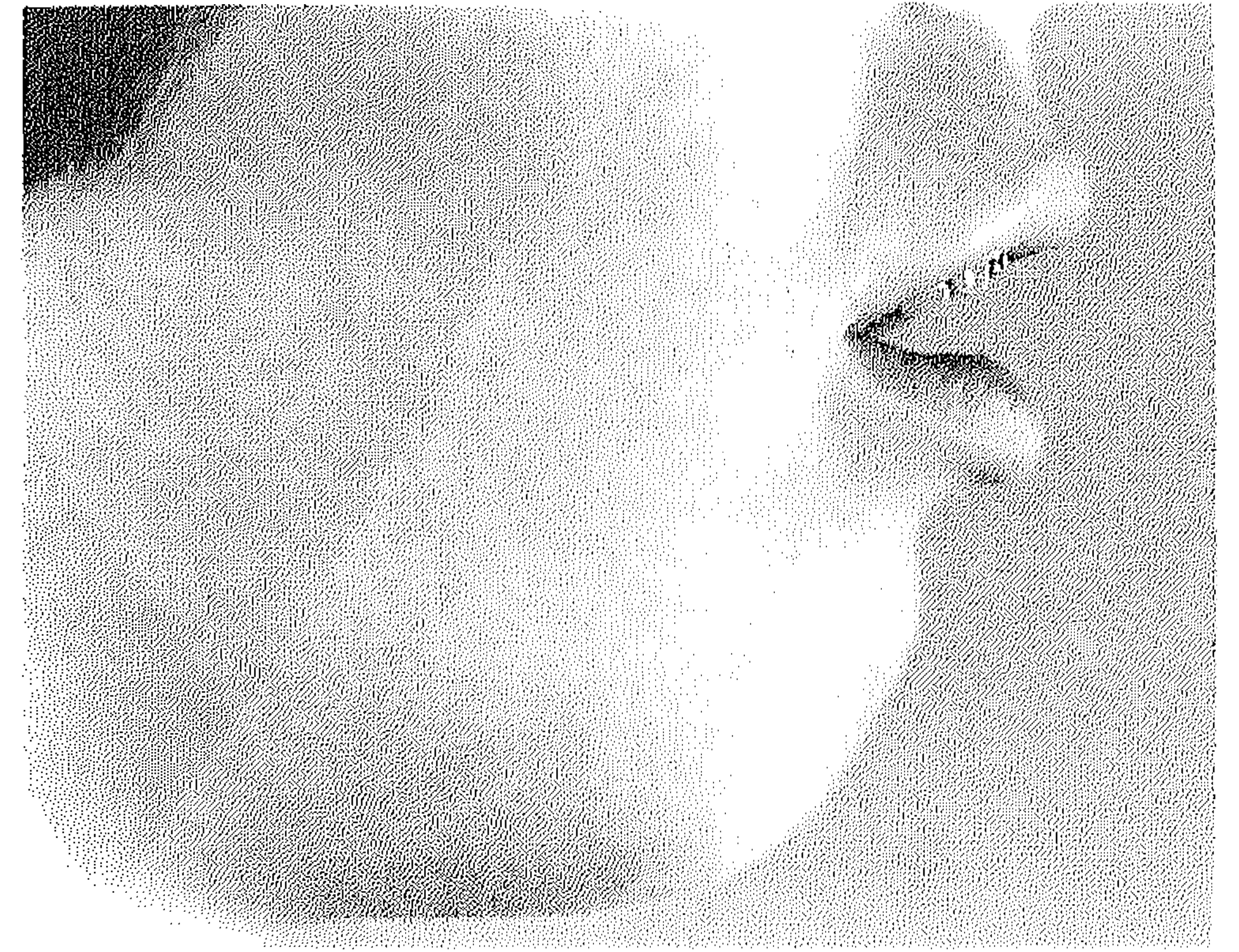
In agreement with other reports, no significant correlations were found



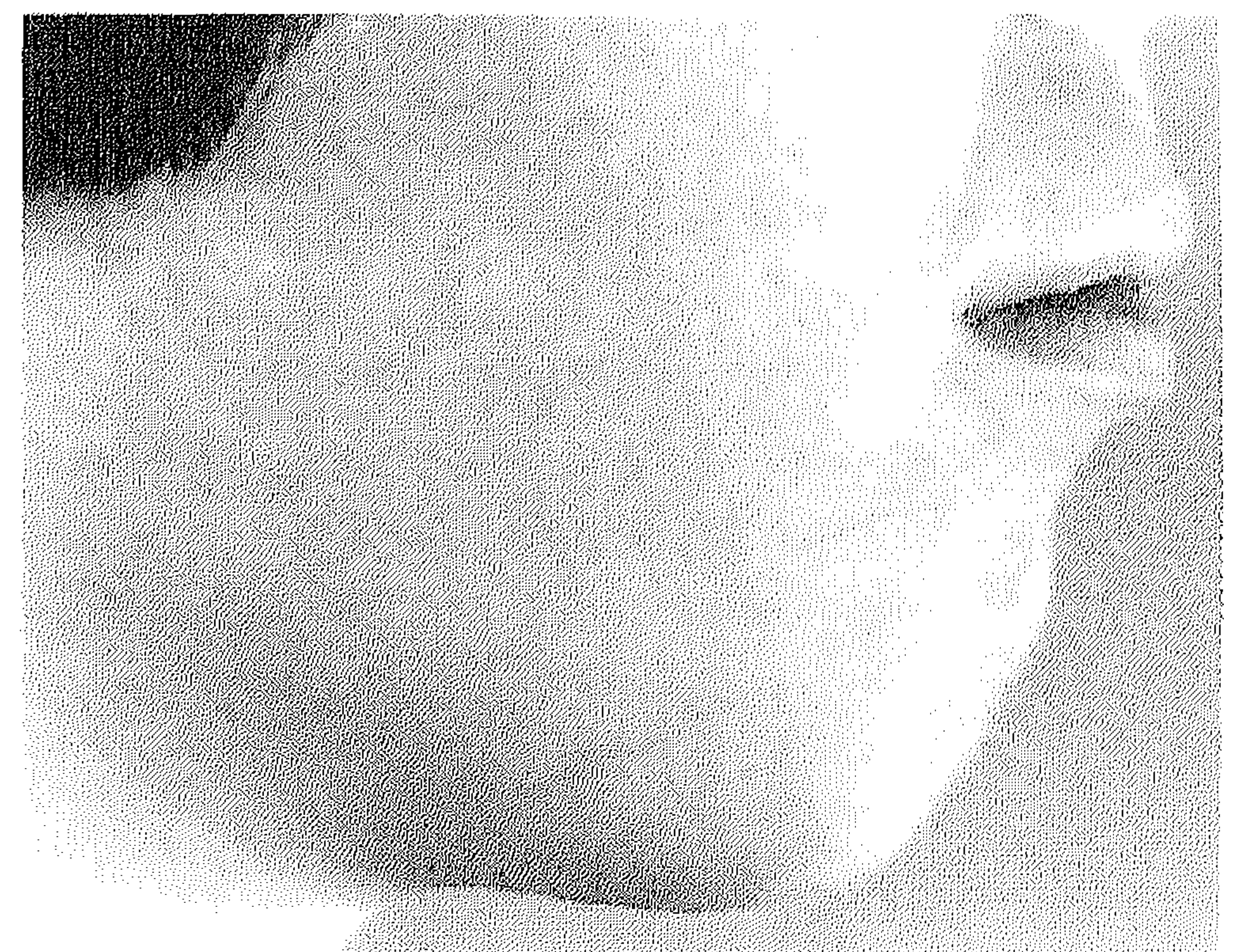
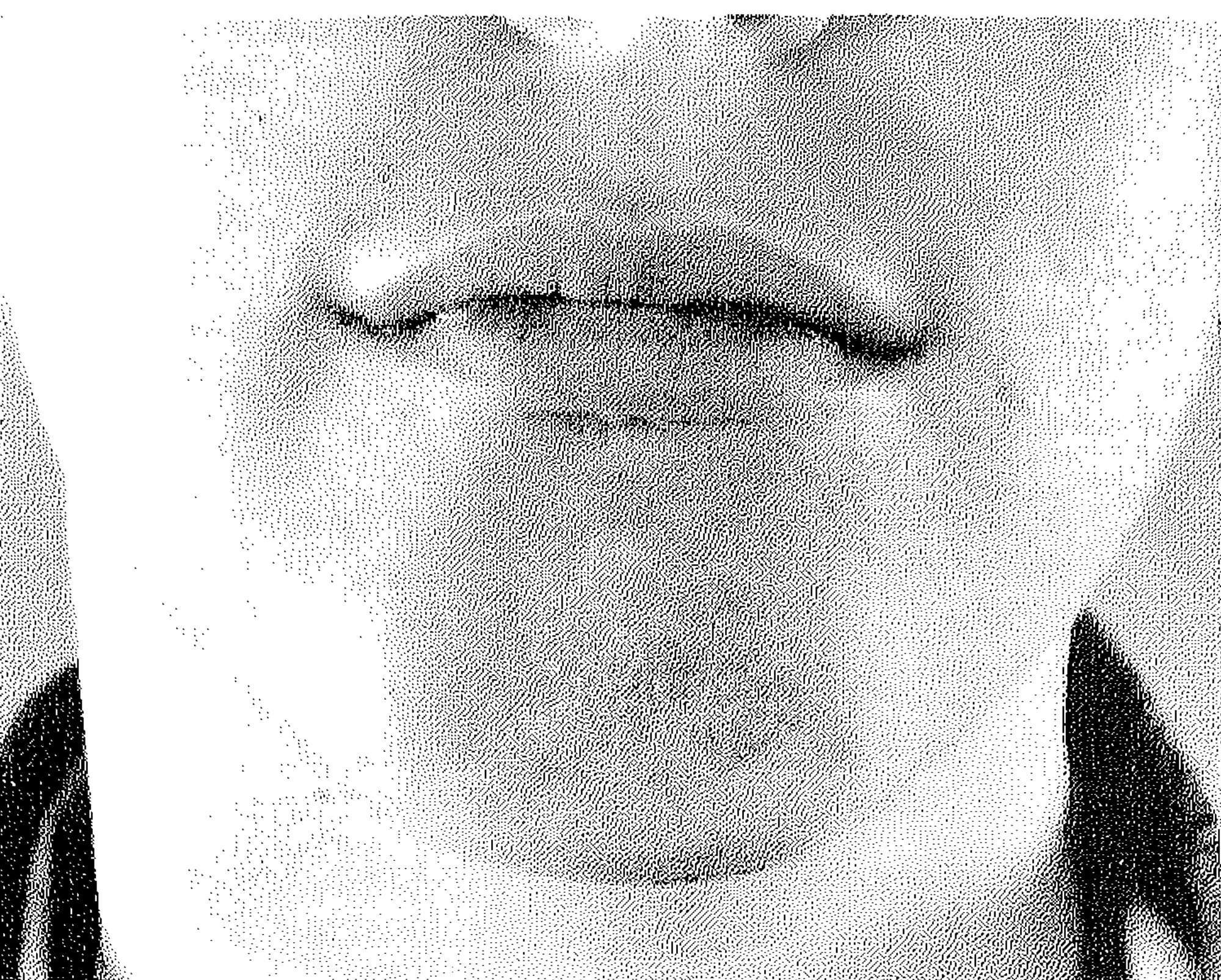
*Fig 4a* A 17-year-old girl underwent preoperative orthodontic treatment for 18 months.



*Figs 4b and 4c* Anterior tongue interposition at rest and during function and lip incompetence (7.0 mm interlabial distance) are present.



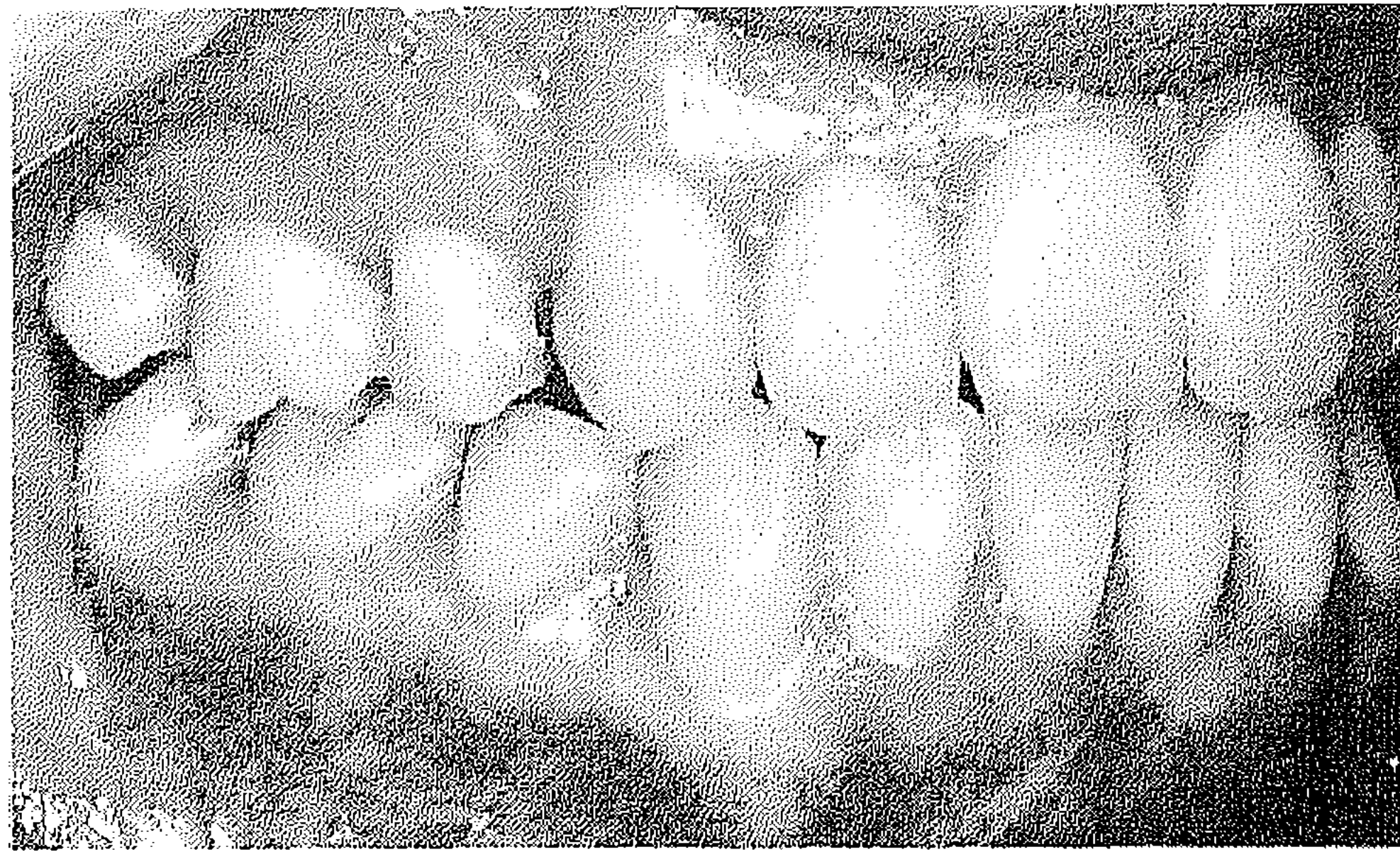
*Figs 4d and 4e* An oral seal can only be achieved by contraction of the mentalis muscle.



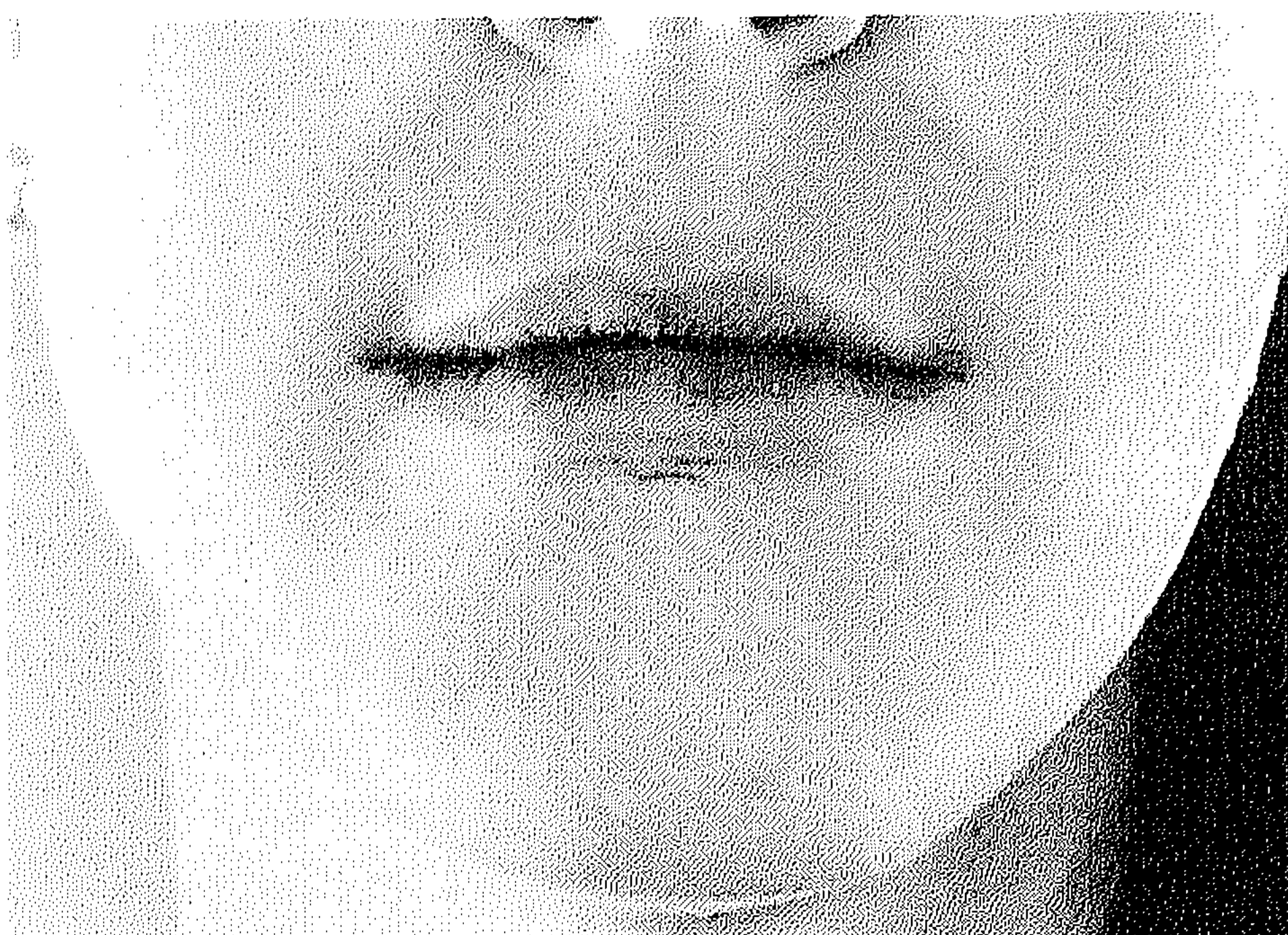
between the postural activity of the upper lip and incisor position.<sup>27,28</sup> Lips are able to adapt to changes in the facial morphology.<sup>29-34</sup> The lower lip and the tongue have more effect on the position of incisors than does the upper lip. The upper lip lacks the muscle activity of

the lower lip, which is anatomically continuous with the mentalis muscle. Lip muscles alone cannot maintain lip closure.<sup>35</sup> A circumoral seal can only be achieved when the lower lip is raised by contraction of the mentalis muscle (Figs 4a to 4h).<sup>36,37</sup>





*Fig 4f* A three-piece Le Fort I intrusion osteotomy with removal of the maxillary first premolars and an additional genioplasty were followed by 3 months of orthodontic treatment. Two years postoperatively, adequate interdigitation and a positive overbite without anterior contact are still present.



*Figs 4g and 4h* Only some tongue interposition between the incisors is apparent during swallowing. The masticatory muscles show high activity during swallowing. A harmonious profile with lip competence has been created.

Indeed, the orofacial muscles are undoubtedly a contributing factor to, but not the sole cause of, relapse after surgical correction of anterior skeletal open bite.<sup>38</sup> The position and fixation of the maxillary and possibly the mandibular fragments are equally important. To achieve good clinical results skeletal fragments should be adequately repositioned, and the occlusion should be as optimal as possible.

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